

VOLUME 12 NO. 2  
DECEMBER 2015

ISSN 1675-7009

# SCIENTIFIC RESEARCH JOURNAL

Institute of Research Management & Innovation (IRMI)

Synthesis and Characterization of Pd(II) and Ni(II) Complexes of Schiff Bases and Catalytic Activity of Pd(II) Complexes

**Amalina Mohd Tajuddin, Hadariah Bahron & Shahrul Nizam Ahmad**

Conductivity Studies of Schiff Base Ligands Derived From O-Phenylenediamine and Their Co(II) and Zn(II) Complexes

**Muhamad Faridz Osman & Karimah Kassim**

Ionic Conductivity Studies on Magnesium-Based Cellulose Acetate Polymer Gel Electrolytes

**Aniza Omar, Siti Zafirah Zainal Abidin, Ainnur Sherene Kamisan,  
Siti Irma Yuana Saaid, Ab Malik Marwan bin Ali & Muhd Zu Azhan bin Yahya**

Vibrational Analysis of  $\text{Li}_{1+x}\text{Al}_x\text{Ti}_{2-x}(\text{PO}_4)_3$  ( $0.0 \leq x \leq 0.5$ ) Glass Ceramic Electrolytes Prepared by Acetic Acid-Assisted Sol-Gel Method

**Maziidah Hamidi, S. N. Mohamed, Raja Ibrahim Putera Raja Mustapha,  
Oskar Hasdinor Hassan & Muhd Zu Azhan bin Yahya**

The Microstructure Investigation of Thionine-Graphene Nanocomposite Using SEM  
**Muhammad Aidil Ibrahim, Nur Atikah Md Jani, Tunku Ishak Tunku Kudin,  
Raihana Mohd Yusof, Ab Malik Marwan Ali & Oskar Hasdinor Hassan**

Kinetics Study of Membrane Anaerobic System (MAS) in Palm Oil Mill Effluent (POME) Treatment

**Abdurrahman H. N., Asdarina Y., Amirah N. F. S., Natrah S. A. R.,  
Norasmah M. M. & Zulkafli H.**

Characterization of Agarwood Incense using Gas Chromatography – Mass Spectrometry (GC-MS) coupled with Solid Phase Micro Extraction (SPME) and Gas Chromatography – Flame Ionization Detector (GC-FID)

**Nurlaila Ismail, Mastura Ibrahim, Seema Zareen, Mohd Hezri Fazalul Rahiman,  
Saiful Nizam Tajuddin & Mohd Nasir Taib**

Ionic Conductivity of MG30-PEMA Blend Solid Polymer Electrolyte

**Siti Fadzilah Ayub, Khuzaimah Nazir, Ahmad Fairuz Aziz,  
Siti Irma Yuana Saaid, Muhd Zu Azhan bin Yahya & Ab Malik Marwan Ali**

# SCIENTIFIC RESEARCH JOURNAL

## Chief Editor

Mohd Nazip Suratman  
Universiti Teknologi MARA, Malaysia

## International Editor

David Shallcross, University of Melbourne, Australia  
Ichsan Setya Putra, Bandung Institute of Technology, Indonesia  
K. Ito, Chiba University, Japan  
Luciano Boglione, University of Massachusetts Lowell, USA  
Vasudeo Zambare, South Dakota School of Mines and Technology, USA

## Editorial Board

Halila Jasmani, Universiti Teknologi MARA, Malaysia  
Hamidah Mohd. Saman, Universiti Teknologi MARA, Malaysia  
Kartini Kamaruddin, Universiti Teknologi MARA, Malaysia  
Tan Huey Ling, Universiti Teknologi MARA, Malaysia  
Mohd Zamin Jumaat, University of Malaya, Malaysia  
Norashikin Saim, Universiti Teknologi MARA, Malaysia  
Noriham Abdullah, Universiti Teknologi MARA, Malaysia  
Saadiah Yahya, Universiti Teknologi MARA, Malaysia  
Norizzah Abdul Rashid, Universiti Teknologi MARA, Malaysia  
Zahrah Ahmad, University of Malaya, Malaysia  
Zulkiflee Abdul Latif, Universiti Teknologi MARA, Malaysia  
Zulhabri Ismail, Universiti Teknologi MARA, Malaysia  
Ahmad Zafir Romli, Universiti Teknologi MARA, Malaysia  
David Valiyappan Natarajan, Universiti Teknologi MARA, Malaysia  
Fazlena Hamzah, Universiti Teknologi MARA, Malaysia  
Nor Ashikin Mohamed Noor Khan, Universiti Teknologi MARA, Malaysia  
Sabarinah Sheikh Ahmad, Universiti Teknologi MARA, Malaysia  
Ismail Musirin, Universiti Teknologi MARA, Malaysia  
Norhati Ibrahim, Universiti Teknologi MARA, Malaysia  
Kalavathy Ramasamy, Universiti Teknologi MARA, Malaysia  
Ahmad Taufek Abdul Rahman, Universiti Teknologi MARA, Malaysia

## Journal Administrator

Fatimatun Nur Zainal Ulum  
Aqilah Ainaa Naraji  
Universiti Teknologi MARA, Malaysia

© UiTM Press, UiTM 2015

All rights reserved. No part of this publication may be reproduced, copied, stored in any retrieval system or transmitted in any form or by any means; electronic, mechanical, photocopying, recording or otherwise; without prior permission in writing from the Director of UiTM Press, Universiti Teknologi MARA, 40450 Shah Alam, Selangor Darul Ehsan, Malaysia. E-mail: [penerbit@salam.uitm.edu.my](mailto:penerbit@salam.uitm.edu.my).

*The views, opinions and technical recommendations expressed by the contributors and authors are entirely their own and do not necessarily reflect the views of the editors, the publisher and the university.*

- |    |  |    |
|----|--|----|
| 1. | Synthesis and Characterization of Pd(II) and Ni(II) Complexes of Schiff Bases and Catalytic Activity of Pd(II) Complexes<br><i>Amalina Mohd Tajuddin</i><br><i>Hadariah Bahron</i><br><i>Shahrul Nizam Ahmad</i>   | 1  |
| 2. | Conductivity Studies of Schiff Base Ligands Derived From <i>O</i> -Phenylenediamine and their Co(II) and Zn(II) Complexes<br><i>Muhamad Faridz Osman</i><br><i>Karimah Kassim</i>  | 13 |
| 3. | Ionic Conductivity Studies on Magnesium-Based Cellulose Acetate Polymer Gel Electrolytes<br><i>Aniza Omar</i><br><i>Siti Zafirah Zainal Abidin</i><br><i>Ainnur Sherene Kamisan</i><br><i>Siti Irma Yuana Saa'id</i><br><i>Ab Malik Marwan Ali</i><br><i>Muhd Zu Azhan Yahya</i> | 25 |
| 4. | Vibrational Analysis of $\text{Li}_{1+x}\text{Al}_x\text{Ti}_{2-x}(\text{PO}_4)_3$ ( $0.0 \leq x \leq 0.5$ ) Glass Ceramic Electrolytes Prepared by Acetic Acid-Assisted Sol-Gel Method<br><i>Maziidah Hamidi</i><br><i>S. N. Mohamed</i>  | 35 |

*Raja Ibrahim Putera Raja Mustapha*  
*Oskar Hasdinor Hassan*  
*Muhd Zu Azhan Yahya*

5. The Microstructure Investigation of Thionine-Graphene  
Nanocomposite Using SEM 45

*Muhammad Aidil Ibrahim*  
*Nur Atikah Md Jani*  
*Tunku Ishak Tunku Kudin*  
*Raihana Mohd Yusof*  
*Ab Malik Marwan Ali*  
*Oskar Hasdinor Hassan*
6. Kinetics Study of Membrane Anaerobic System (MAS)  
in Palm Oil Mill Effluent (POME) Treatment 53

*Abdurrahman Hamid Nour*  
*Asdarina Yahya*  
*Amirah N. F. S.*  
*Siti Natrah Abdul Rahman*  
*Norasmah Mohammed Manshor*  
*Zulkafli Hassan*
7. Characterization of Agarwood Incense Using Gas  
Chromatography – Mass Spectrometry (GC-MS) Coupled  
with Solid Phase Micro Extraction (SPME) and Gas Chromatography –  
Flame Ionization Detector (GC-FID) 67

*Nurlaila Ismail*  
*Mastura Ibrahim*  
*Seema Zareen*  
*Mohd Hezri Fazalul Rahiman*  
*Saiful Nizam Tajuddin*  
*Mohd Nasir Taib*
8. Ionic Conductivity of MG30-PEMA Blend Solid Polymer  
Electrolyte 83

*Siti Fadzilah Ayub*  
*Khuzaimah Nazir*  
*Ahmad Fairuz Aziz*  
*Siti Irma Yuana Saa'id*  
*Muhd Zu Azhan Yahya*  
*Ab Malik Marwan Ali*



# Conductivity Studies of Schiff Base Ligands Derived from O-Phenylenediamine and Their Co(II) and Zn(II) Complexes

Muhamad Faridz Osman<sup>1</sup> and Karimah Kassim

*Faculty of Applied Sciences,  
Universiti Teknologi MARA,  
40450 Shah Alam, Selangor, Malaysia  
<sup>1</sup>E-mail: faridzchem@yahoo.com*

## ABSTRACT

*The coordination complexes of Co(II) and Zn(II) with Schiff bases derived from o-phenylenediamine and substituted 2-hydroxybenzaldehyde were prepared. All compounds were characterized by Fourier transform infrared (FTIR) spectroscopy and Nuclear magnetic resonance (NMR) spectroscopy elemental analyzers. They were analyzed using impedance spectroscopy in the frequency range of 100Hz–1MHz. L1 and L2 showed higher conductivity compared to their metal complexes, which had values of  $1.37 \times 10^{-7}$  and  $6.13 \times 10^{-8}$  S/cm respectively.*

**Keywords:** Schiff base, o-phenylenediamine, 2-hydroxy-3-methoxybenzaldehyde, 2-hydroxy-5-nitrobenzaldehyde, conductivity

## INTRODUCTION

Coordination chemistry, the chemistry of metal complexes is one of the most significant research areas in inorganic chemistry due to their facile synthesis and wide range of applications as antifungal, antibacterial, anticancer and anti-inflammatory agents, as well as their insecticidal and catalytic properties [1,2] which plays a major role in our lives. Schiff base ligands are able to coordinate with different metals and stabilize them in various oxidation states since they show electronic and magnetic properties [3]. In this paper, we report the synthesis, characterization and conductivity studies

of Cu(II) and Ni(II) complexes with 6,6'-(1*E*,1'*E*)-(1,2-phenylenebis(azan-1-yl-1-ylidene))bis(methan-1-yl-1-ylidene)bis(2-methoxyphenol) (L1) and 2,2'-(1*E*,1'*E*)-(1,2-phenylenebis(azan-1-yl-1-ylidene))bis(methan-1-yl-1-ylidene)bis(4-nitrophenol) (L2). We focused on conjugated compounds which are more stable due to the effectiveness of their conjugation system [4]. Both ligands were synthesized using the same amine, which is *o*-phenylenediamine and substituted 2-hydroxybenzaldehyde.

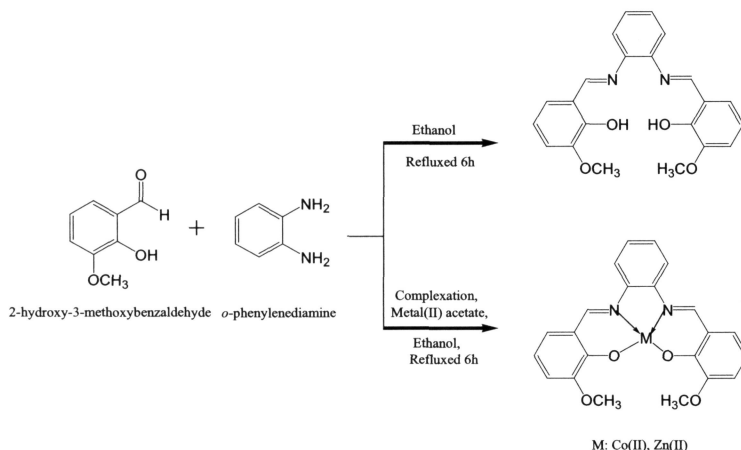
## MATERIALS AND METHODS

### Preparation of Schiff Base Ligand (L1)

A Schiff base ligand 6,6'-(1*E*,1'*E*)-(1,2-phenylenebis(azan-1-yl-1-ylidene))bis(methan-1-yl-1-ylidene)bis(2-methoxyphenol) (L1) was successfully synthesized by condensation of 2-hydroxy-3-methoxybenzaldehyde and *o*-phenylenediamine in a 2:1 ratio. Both starting materials were dissolved separately in 25 cm<sup>3</sup> of ethanol. The yellow solution of 2-hydroxy-3-methoxybenzaldehyde was added to the *o*-phenylenediamine solution. The resulting orange mixture was refluxed for 6 h. Then, the product was filtered off, washed with diethyl ether and left to dry for a few days. The dried product was then collected.

### Preparation of Metal Complexes (L1Co, L1Zn)

Metal complexes were prepared by the *in situ* method using 2-hydroxy-3-methoxybenzaldehyde, *o*-phenylenediamine and cobalt(II) acetate tetrahydrate mixed at a ratio of 2:1:1, by refluxing for 6 h in ethanol. The solution was then allowed to cool at room temperature, and the solvent removed using a rotary evaporator. After that, the product was filtered off and washed with diethyl ether. The final product was collected after being air dried. The same procedure was repeated for Zn(II) complexes.



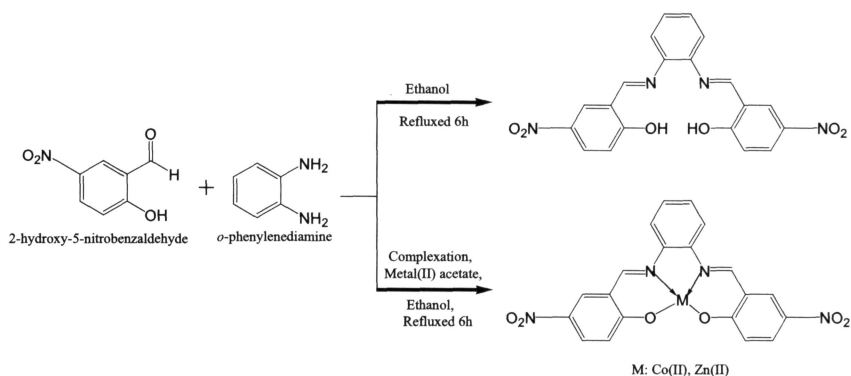
**Figure 1: Reaction Scheme of the Preparation of L1 and its Complexes**

## Preparation of Schiff Base Ligand (L2)

Schiff base ligand 2,2'-(1*E*,1'*E*)-(1,2-phenylenebis(azan-1-yl-1-ylidene))bis(methan-1-yl-1-ylidene)bis(4-nitrophenol) (L2) was synthesized from the condensation of 2-hydroxy-5-nitrobenzaldehyde and *o*-phenylenediamine mixed at a ratio of 2:1 using ethanol as a solvent. Both starting materials were mixed and heated to reflux for 6 h. The product was filtered off and washed with diethyl ether. It was then left to air dry for few days before collection.

## Preparation of Metal Complexes (L2Co, L2Zn)

Metal complexes were prepared by the in-situ method using 2-hydroxy-5-nitrobenzaldehyde, *o*-phenylenediamine and cobalt(II) acetate tetrahydrate mixed at a ratio of 2:1:1, by refluxing for 6 h in ethanol. The solution was then allowed to cool at room temperature and the solvent removed by using a rotary evaporator. After that, the product was filtered off and washed with diethyl ether. The final product was collected after being air dried. The same procedure was repeated for Zn(II) complexes.



**Figure 2: Reaction Scheme of the Preparation of L2 and its Complexes**

## RESULTS AND DISCUSSION

### Elemental Analysis

The physical characteristics of metal complexes are summarized in Table 1. Elemental analysis showed that the experimental values were in agreement with the theoretical values for all compounds.

**Table 1: Analytical Data and Physical Properties of Schiff Base Ligands and their Metal Complexes**

Compound	Melting point (°C)	Yield (%)	Experimental Value (Calculated Value) (%)		
			C	H	N
<b>L1</b>	170.0	73.67	70.08 (70.20)	5.22 (5.36)	7.70 (7.44)
<b>L1Co</b>	247.3	70.63	54.19 (54.22)	4.57 (4.96)	5.35 (5.75)
<b>L1Zn</b>	261.6	77.10	57.66 (57.72)	4.67 (4.40)	6.01 (6.01)
<b>L2</b>	275.3	88.85	58.55 (59.12)	3.62 (3.47)	13.76 (13.79)
<b>L2Co</b>	>300	82.88	48.57 (51.85)	3.55 (2.61)	11.71 (12.09)
<b>L2Zn</b>	>300	86.20	47.48 (47.58)	3.64 (3.33)	9.58 (9.25)



## Infrared Spectroscopy

Infrared spectroscopy was used to determine part of the structural information of a molecule. Structural information was determined by the presence or absence of a particular functional group in the structure. In this study structural analysis was carried out using the Perkin Elmer 1750X FTIR. Table 2 summarizes important peaks at different frequencies that appeared in the spectra for all compounds. In the IR spectrum of ligand L1, a peak at  $1614\text{ cm}^{-1}$  was attributed to the C=N stretching band of the structure. After complexation with metal ions, the C=N band was shifted to lower frequencies between  $1611$  and  $1614\text{ cm}^{-1}$ , indicating the coordination of nitrogen atom to the central metal ion. The coordination of nitrogen to the metal ion reduced the electron density of the azomethine link and caused a shift in the frequency of the C=N group [5]. The phenolic C-O stretching in free ligand L1 appeared at  $1256\text{ cm}^{-1}$ . For complexes, the C-O stretching shifted to lower frequency in the region of  $1237$  to  $1244\text{ cm}^{-1}$  due to the participation of the oxygen atom of the phenolic group in coordination with metal ions. New bands were observed in the spectra of both metal complexes in the regions of  $509$  to  $526\text{ cm}^{-1}$  and  $421$  to  $454\text{ cm}^{-1}$ , characteristic to M-N and M-O stretching vibrations, respectively. No metal-nitrogen and metal-oxygen peaks were observed in the spectrum of ligand L1 since it does not contains any metal. In the free L2 ligand, the C=N stretching band appeared at  $1622\text{ cm}^{-1}$ . After complexation, the C=N stretching band shifted to lower frequencies of  $1544$  and  $1525\text{ cm}^{-1}$  for Co(II) and Zn(II) complexes, respectively. The phenolic C-O stretching of L2 was observed at  $1350\text{ cm}^{-1}$  while for both complexes they appeared at higher frequencies of  $1351$  to  $1393\text{ cm}^{-1}$ . New peaks were observed at  $500$  to  $542\text{ cm}^{-1}$  and  $413$  to  $422\text{ cm}^{-1}$  representing M-N and M-O stretching vibrations, respectively. There were no observed M-N and M-O peaks for L2. N-O stretching frequencies were observed in the L2 spectrum. Symmetrical and asymmetrical N-O stretching vibrations appeared at  $1487$  and  $1525\text{ cm}^{-1}$ , respectively [6]. For L2Co and L2Zn, symmetrical and asymmetrical N-O stretching vibrations were observed in the region of  $1444$  to  $1487\text{ cm}^{-1}$  and  $1505$  to  $1526\text{ cm}^{-1}$ , respectively.

**Table 2: Stretching Frequencies of Schiff Base Ligands and their Metal Complexes (cm<sup>-1</sup>)**

Compound	Wavelength (cm <sup>-1</sup> )				
	$\nu(\text{C}=\text{N})$	$\nu(\text{C}-\text{O})$	$\nu(\text{NO}_2)$	$\nu(\text{M}-\text{N})$	$\nu(\text{M}-\text{O})$
<b>L1</b>	1614	1256	-	-	-
<b>L1Co</b>	1614	1244	-	526	454
<b>L1Zn</b>	1611	1237	-	509	421
<b>L2</b>	1622	1350	1487, 1525	-	-
<b>L2Co</b>	1544	1393	1444, 1505	542	422
<b>L2Zn</b>	1525	1351	1487, 1526	500	413

### Magnetic Susceptibility

Magnetic susceptibility is a study of the degree of magnetization of a material in response to an applied magnetic field. The magnetic susceptibility value indicates the number of unpaired electron of a material. The value can be used to determine the geometric structure of a compound. By doing this, we can also determine the spin state whether its exhibit high spin or low spin behavior. Magnetic susceptibility of all compounds were measured at room temperature. The data is shown in Table 3. Co(II) complexes had effective magnetic moment values of 3.60 B.M and 3.60 B.M for L1Co and L2Co, respectively. Those values indicate three unpaired electron. According to the Crystal Field Splitting Theory, tetrahedral geometries for Co(II) complexes having three unpaired electron are as shown in Figure 3. Therefore, the geometry for L1Co and L2Co is tetrahedral. For Zn(II) complexes, both tetrahedral and square planar geometries splitting diagram of Zn(II) showed 0 unpaired electrons, indicating a diamagnetic nature. Since Zn(II) complexes had no unpaired electrons, they exhibited tetrahedral or square planar geometry (Figure 4).

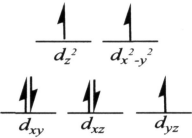
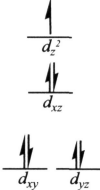
Tetrahedral	Square Planar
<p style="text-align: center;">Co(II) <math>3d^7</math></p>  <p style="text-align: center;">3 unpaired electron</p>	<p style="text-align: center;">Co(II) <math>3d^7</math> <math>d_{x^2-y^2}</math></p>  <p style="text-align: center;">1 unpaired electron</p>

Figure 3: Crystal Splitting Diagram of Co(II) Complexes

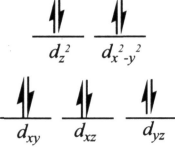
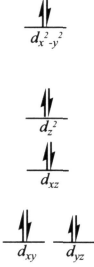
Tetrahedral	Square Planar
<p style="text-align: center;">Zn(II) <math>3d^{10}</math></p>  <p style="text-align: center;">0 unpaired electron</p>	<p style="text-align: center;">Zn(II) <math>3d^{10}</math> <math>d_{x^2-y^2}</math></p>  <p style="text-align: center;">0 unpaired electron</p>

Figure 4: Crystal Splitting Diagram of Zn(II) Complexes

**Table 3: Magnetic Susceptibility Data of Metal Complexes**

Compound	$\mu_{\text{eff}}$ (B.M)	Number of unpaired electron	$d^n$	Suggested geometry
<b>L1Co</b>	3.67	3	$d^7$	Tetrahedral
<b>L1Zn</b>	Diamagnetic	0	$d^{10}$	Tetrahedral/ Square planar
<b>L2Co</b>	3.60	3	$d^7$	Tetrahedral
<b>L2Zn</b>	Diamagnetic	0	$d^8$	Tetrahedral/ Square planar

### Conductivity Measurement

All synthesized compounds were further analyzed for their conductivity using impedance spectroscopy at room temperature. The analysis was conducted to observe the effect of complexation on the conductivity values of these Schiff base compounds. Conductivity of all compounds were measured using an impedance analyzer by applying alternating current (ac) voltage. The samples (0.25 g) were prepared in the form of pellets and their thickness measured. The pellets were then placed between two stainless steel blocking electrodes. Alternating current impedance spectroscopy (IS) was measured by using the Solartron Impedance 1260 in the frequency range of 100 Hz to 1 MHz at room temperature. Conductivity value was calculated using the following formula:

$$\frac{T}{R_b A} \quad (1)$$

Where  $T$  = thickness of the pellet  
 $R_b$  = bulk resistance  
 $A$  = surface area of the pellet



**Table 4: Conductivity Value Calculated**

<b>Compound</b>	<b>Conductivity (S/cm)</b>
<b>L1</b>	$1.37 \times 10^{-7}$
<b>L1Co</b>	$9.31 \times 10^{-8}$
<b>L1Zn</b>	$1.63 \times 10^{-8}$
<b>L2</b>	$6.13 \times 10^{-8}$
<b>L2Co</b>	$2.65 \times 10^{-8}$
<b>L2Zn</b>	$1.71 \times 10^{-8}$

## Optical Properties

Measurement of the optical property represented by the band gap energy was done to support the conductivity data. The result can be acquired by conducting UV-Vis experiment. Optical band gap values can be obtained using the following equation:

$$\frac{hC}{\lambda_{\text{onset}} (1.6 \times 10^{-19})} \quad (2)$$

Where  $\lambda_{\text{onset}}$  = wavelength value from two tangents on the absorption edges

$h$  = Planks constant

$C$  = speed of light

The optical band gap energy is the energy taken by an electron to move from the Highest Occupied Molecular Orbital (HOMO) to the Lowest Unoccupied Molecular Orbital (LUMO). Table 5 shows the band gap energy of all synthesized compounds. Results of the optical band gap energy supports the conductivity values. The large optical band gap indicates that it was more difficult for electrons to excite from HOMO to LUMO, thereby reducing conductivity values. Conductivity values increase with decreasing band gap energy.

**Table 5: Band Gap Energy of Schiff Base Ligands and their Metal Complexes**

<b>Compound</b>	<b>Band Gap Energy (eV)</b>
<b>L1</b>	1.56
<b>L1Co</b>	2.69
<b>L1Zn</b>	2.53
<b>L2</b>	1.38
<b>L2Co</b>	1.45
<b>L2Zn</b>	1.75

## CONCLUSION

Two Schiff base ligands with their Co(II) and Zn(II) complexes were synthesized and characterized. Conductivity studies showed that both ligands had higher conductivity values compared to metal complexes. Measurement of optical properties represented by the band gap energy was carried out to support the conductivity data.

## ACKNOWLEDGEMENT

The authors express their thanks to the Faculty of Applied Sciences for the funding and Ministry of Education (MOE) for the research grant 600-RMI/FRGS 5/3 (51/2013) and for MyMaster Scholarship. Thanks also to Faculty of Applied Sciences and Institute of Science, Universiti Teknologi MARA for providing research facilities.

## REFERENCES

- [1] Chem, D. Arish, M. S. Nair, 2001. Synthesis, spectroscopic, antimicrobial, DNA binding and cleavage studies of some metal complexes involving symmetrical bidentate N, N donor Schiff base ligand. *Spectrochimica Acta Part A* 82, 2011, 191-199.
- [2] S. Patil, S. D. Jadhav, U. P. Patil, 2012. Natural acid catalyzed synthesis of Schiff base under solvent-free condition: As a green approach. *Archive of Applied Science Research*. 4 (2): 1074-1078.
- [3] S. Annapoorani, C. N. Krishnan, 2011. Studies on some trinuclear Schiff base complexes. *International Journal of ChemTech Research*, 3(4): 1962-1968.
- [4] S. A. Abbas, M. Munir, A. Fatima, S. Naheed, Z. Ilyas, 2010. Synthesis and analytical studies of sulfadimidine-imine Schiff base complexes with Ni(II) and Cu(II). *The BIOL (E-Journal Life of Science)*, 1(2): 37-40.
- [5] X. Ran, L. Wang, Y. Lin, J. Hao, D. Cao, 2010. Synthesis, characterization and biological studies of zinc(II), copper(II) and cobalt(II) complexes with Schiff base ligand derived from 2-hydroxy-1-naphthaldehyde and selenomethionine. *Applied Organometallic Chemistry*, 24, 741-747.
- [6] Pavia, Lampman, Kriz, Vyvyan, 2007. *Introduction to Spectroscopy* (4<sup>th</sup> edition). Brooks/Cole Cengage Learning.
- [7] A. Cukurovali, I. Yilmaz. A new cyclobutane substituted Schiff base ligand, synthesis of its Cd(II), Co(II), Cu(II), Ni(II) and Zn(II) complexes and investigation of their structure. *J. Coord.*, 53. pp. 329-337.